signs of stratification, and no visible contacts with underlying or overlying beds. Cleavage is well developed.

Criteria found: — A, B, C, D, J, L.

Locality 6. Forest Hills Cemetery. In the Forest Hills Cemetery there is a small outcrop of tillite. This rock may be found about 100 feet from the fence north of Walkhill St., opposite the crematorium. Here the strike at the contact with slate is N 72° E, and the dip 70° S. It is not possible to obtain the thickness. About twenty-five feet are exposed. Measuring toward the west there is a distance of 335 feet to an outcrop of sandstone, and the latter is exposed twenty-five feet. The sandstone is in contact with the main body of the Roxbury conglomerate. The characters of the tillite are much like those at Squantum Head, to be described later. Thin layers of shale or slate may be seen in the tillite a few feet from the slate contact. The matrix is arenaceous; the pebbles of all shapes, angular, subangular, and rounded. The materials of the pebbles are the same as at all the exposures with no additional varieties yet found. The largest fragment found was about one foot in diameter. Several shale or slate fragments were found mixed with the pebbles. There are no transition-beds to the Cambridge slate, and in this the deposit resembles that at Squantum Head. Cleavage is well developed. No striated pebbles were found.

Criteria found: — A, B, C, D, J, L, M, O.

Locality 7. New Calgary Cemetery. At New Calgary Cemetery, one fifth of a mile south of Walkhill St., close to the fence on the east, a small outcrop of what appears to be tillite may be seen. The strike of the beds just south is E 6° S, and the dip 76° W. The thickness here is not obtainable. The matrix is a gritty argillite. No stratification is visible. The pebbles have angular, subangular, and rounded shapes. The position of this bed is right for tillite, the transition-beds coming to the south, and south of these the main body of the Roxbury conglomerate, while to the north comes thick slate. Very little more can be said of this outcrop except that the pebbles so far as visible are of granite, and felsite.

Criteria found: — A, B, C, D, J.

Locality 8. Morton Street. About fifty feet south of Canterbury Street on Morton Street there is an outcrop which resembles very closely the tillite at the junction of Blue Hill Avenue and Harvard Street. No strike or dip have been obtainable. The matrix is arenaceous. Pebbles are angular, subangular, and rounded. Cleavage noted.

Criteria found: — A, B, C, D, F, H, J, L, M.

Locality 9. Franklin Field. At the junction of Blue Hill Avenue and Harvard Street there is an outcrop of tillite. No strike or dip are available. The breadth of the outcrop is about 100 feet. The matrix is a sandy slate. The included rock fragments are angular, subangular, and rounded. One striated pebble has been found. This pebble is shown in Plate 10. Blunted and bevelled stones are common. Several concave fractures have been found. The rock fragments are composed of granite, felsite, and quartzite. I have not found melaphyre, and there are no slate masses. There are no intercalated layers. The transition-bed or beds to the Roxbury formation are conglomerate, and not slate or sandstone as in localities farther south and southeast. Shearing was as intense at this locality as at any other.

Criteria found: — A, B, C, D, E, F, G, H, J, K, L.

Locality 10. Atlantic. About one half of a mile southwest of the aviation field at Atlantic, on a wooded knoll, a very important exposure of the tillite may be seen. The series of beds here commences well down in the Roxbury conglomerate proper, and in almost continuous outcrops ends near the middle of the tillite. This is the best exposure of the beds underlying the tillite, with the tillite bed itself well exposed. Commencing at the most northern extremity of the knoll the Roxbury has a strike of N 42° E, with a dip of 45° S. The transition-beds below the tillite have a strike of N 48° E, and a dip of 70° S. Thicknesses of beds in this section are as follows: — Roxbury conglomerate 520 feet; a sandstone bed twenty-five feet; conglomerate, sandstone, and slate 120 feet; contorted slate and sandstone forty-seven feet; conglomerate and sandstone 123 feet; tillite 298 feet. This gives a total for the section of 1,133 feet. In correcting the thickness of the Roxbury conglomerate an average dip of 57° was used, the dip at the bottom being 45° and at the contact with the first bed of sandstone 70°.

At this point it is necessary to describe some of the beds underlying the tillite, for the reason that two of these beds resemble a bed in Brighton. About fifty feet above the main body of the Roxbury formation, and just above a sandstone layer about 3 feet thick, there appears a bed of conglomerate with thin layers of slate and fragments of slate. These fragments are very irregular in shape and vary in size, although most of them are not over six inches in diameter. It is evident that this deposit is water laid, and that the fragments have been washed along with the pebbles. In view of the fact that much larger fragments of slate are found in the tillite at Squantum and

Atlantic, and that the same kind of argillaceous masses are found in the tillite of Australia (Wilkinson, p. 194) and other places, and in Pleistocene till, it is necessary to suppose — unless some better agency can be advanced — that moving ice tore up all these shale or slate fragments. A moving ice-sheet would tear up a clay-bed; part of the torn up mass would be over-ridden and dragged up into the till, and some of it would be seized by the glacial torrents and carried forward and deposited somewhere in front of the ice. It seems perfectly possible that this latter method explains these lumps deposited with the conglomerate. A large fragment would be rolled over along the bottom more easily than a rock of corresponding size, on account of the lower specific gravity of clay and lessened liability to wedging on account of ready marcellation when moved against an obstacle. In this way a large fragment might be moved for some distance and when finally brought to rest would be much reduced in size.[1] As for the fragments at Atlantic, the ice-front could not have been very far away, and a retreat must have followed, for above this horizon a slate bed is found. Another advance is indicated by another conglomerate bed with slate fragments and tillite. Above these beds come about 25 feet of sandstone with fine conglomeratic layers, and some shale or slate fragments, and in contact with this the main body of the tillite. Knowing that moving ice does disrupt clay-beds, and the proximity of the tillite to these shale or slate fragment horizons, this association makes it very probable that ice was the agency responsible for the fragments. I am well aware that such fragments may also be due to the undermining of clay-beds by streams, and the falling in of clay fragments so undermined, but the evidence in these cases under consideration points to ice-action.

The tillite has a very ragged contact with this underlying sandstone, as if the surface of that deposit had been disrupted by violent movement such as that of ice. In places the tillite appears to have been pushed down into the sandstone. The lower part has a fine argillaceous matrix with here and there coarse patches. About ten feet from the bottom the matrix is uniformly fine. Farther up in this main tillite bed the matrix becomes coarser and at the point highest up resembles very closely the tillite at Squantum Head.

[1] By experiment I have found that frozen clay disintegrates as soon as it comes in contact with water. The temperature of the water used was about 32° F. Plastic clay in an unfrozen condition does not disintegrate with anything like the same rapidity. It is inferred from this that the clay fragments under discussion were not frozen.

The included fragments at the bottom are composed of granite, melaphyre, felsite, quartzite, and very large masses of slate. The largest of the last measures at least six feet long by four feet wide. These slate fragments become scarcer upward, and almost disappear. As this exposure has been found very recently, no striated pebbles have as yet been discovered. The boulders, boulderets, and pebbles observed are angular and subangular for the most part, with rounded water-worn individuals here and there. Pink granite predominates over all other varieties of rock. This is true both for the underlying Roxbury conglomerate and the tillite. Melaphyre is well represented and in large fragments, as at the Squantum exposures. An intercalated bed of conglomerate about two feet thick in the tillite, about 150 feet above the sandstone is the equivalent of a similar but thicker bed at Squantum Head. Such beds in tillite are very variable. Shearing has given a well-developed cleavage with sharp dips in a northerly direction.

Criteria found: — A, B, C, D, F, H, J, K, L, M.

Locality 11. Atlantic-Squantum Knoll. To the north of Atlantic on the road to Squantum and about three fourths of a mile southeast of the aviation field there is a little wooded knoll where tillite is exposed. It is not possible to be sure of strike or dip. Some intercalated beds occur on the shore, but they appear to be in blocks which have been moved by Pleistocene ice-action. About 100 feet of the tillite bed is exposed in separate outcrops. The matrix at this exposure is very fine, suggesting the lower part of the tillite. The included pebbles, boulderets, and boulders are of granite, melaphyre, felsite, and quartzite. The shapes of the fragments are as usual, angular and subangular, with a very few water-worn pebbles. As this exposure has been discovered very recently no search for striated pebbles or other marks of glaciation has been made. A block of melaphyre was found in the southeastern extremity of the outcrop showing a very angular outline. This block measures four feet long and one foot wide. Cleavage is well marked.

Criteria found: — A, B, C, D, J, K, L, M.

Dr. F. H. Lahee, of the Massachusetts Institute of Technology, has examined a specimen of tillite from this locality and writes me (14 February, 1913) as follows: —

"The specimen of tillite, from which I had the two thin sections made, was obtained on the eastern coast of a small hill at the head of Quincy Bay, three quarters of a mile southeast of the aviation field (Locality 11).

"The exposures at this place are large blocks which show occasional well marked, laminated strata of a fraction of an inch to two feet in thickness. Since these beds all dip vertically and strike in the same direction, I believe that they are practically *in situ*. Alternating with these strata are layers that absolutely lack any evidence of water sorting and water deposition.

"The sorted layers, sometimes of uniform width for many feet, consist of mudstone and sandstone. In the thickness of the entire cliff section they may represent 15 or 20 percent. The unsorted layers contain angular and irregularly shaped fragments of pinkish granite (the species so common in the Roxbury conglomerate), gray quartzite, greenish felsite, and dark green, chloritized melaphyre. There are some rounded pebbles. These fragments and pebbles are very variable in size. They range from grains of quartz and feldspar $\frac{1}{16}$ to $\frac{3}{16}$ of an inch in diameter to large boulders, the largest seen being four feet long. They are contained in a compact, greenish gray paste or matrix which comprises 50 to 75 percent of the bulk of the rock. Having no parallel structure of any sort — bedding or schistosity — the paste breaks with an uneven fracture. Although the term 'tillite' is applicable to the whole section, I use it here with reference only to the unstratified, unsorted portions. My thin sections were cut from a hand specimen of this tillite.

"When examined with the microscope, the finer part of the rock is found to be composed of minute grains of quartz and feldspar, very small laths of sericite, and a highly refracting, granular substance, uniformly distributed, which is probably epidote. The quartz and feldspar are so fine that little can be distinguished. The sericite laths show a tendency to parallel orientation, thus indicating some shearing in the rock, but not enough to produce a visible schistosity in the hand specimen. The laths are small and of nearly uniform dimensions. The paste may be said to consist of particles having the same size as these laths, or smaller. This mica constitutes between 20 % and 25 % of the matrix.

"In the paste are scattered grains of quartz and feldspar and small fragments of granite, quartzite, and melaphyre, as seen in the hand specimen. These grains and fragments are usually angular. The larger quartz particles exhibit slight wavy extinction and some cracking, and also fine peripheral granulation accompanied by the marginal insertion of sericite laths, characteristic of the early stages of dynamic metamorphism. Of the feldspar grains, examples of orthoclase, microcline, microperthite, and plagioclase (albite to oligoclase) were determined. While most of these are considerably altered, either to sericite or to calcite, as the case may be, a few are remarkably clear and fresh.

"Now, as regards the origin of this tillite, there are two agents which have been ascribed to its formation,— vulcanism and ice. If this were a product of extrusive action, it would be called a tuff or an agglomerate, and in either case it should reveal signs of a former glassy nature of all or part of its components. To my mind, there is no suggestion of such an original structure. The rock does not at all resemble the tuffs and agglomerates found elsewhere in the Boston basin. On the other hand, if this were a typical till in a consolidated state, its finer parts should be composed largely of rock-flour; kaolin should not be an abundant constituent. Unfortunately the finer portion of the feldspar elements has gone to form sericite and calcite, and the original source of these secondary minerals is therefore not determinable; but the considerable amount of larger feldspar grains, many of them very little altered, suggests that kaolin was not abundant originally.

"In conclusion, then, I may say that the megascopic and microscopic study of this rock lead me to believe that ice was the most important factor in its deposition; but that water, too — standing or gently moving — was concerned in its origin. I could find no evidence of contemporaneous erosion throughout this section. Both upward and downward, stratigraphically, in the section, the tillite beds grade into the water-laid strata. Apparently the ice was either floating or had its weight much reduced by partial flotation."

In the above letter Dr. Lahee suggests possible flotation for the ice. I have not found any evidence that such was the case. In view of the large fragments of slate in the tillite, and the disrupted beds found at Squantum Southeast, not to mention the immense block of sandstone, fifteen feet in diameter, which is evidently part of a disrupted bed, I cannot agree with Dr. Lahee on the flotation idea. Again the first beds encountered at the top of the tillite are conglomerate of coarse texture, sandstone layers, then sandstone and slate, and last slate without sandstone. These beds would indicate that the water in front of the ice was at first shallow, and the slate would indicate that subsidence was in progress as the ice retreated. This transition may be seen to best advantage at the most southerly part of the Squantum Southeast exposure where the slate appears on the shore.

Locality 12. Squantum Southeast. At the end of the road running farthest east on the peninsula of Squantum there are found many exposures of the tillite, and these different exposures range from near the bottom to the very top of the tillite, with transition-beds to the overlying slate. The strike of the slate here is N 63° E, and the dip 68° S. The thickness of the tillite is probably about 600 feet. The matrix near the bottom is argillaceous, while higher up and at the top it is a gritty argillite, and in one place is arenaceous. Boulders of many kinds may be found, but the largest and most numerous are of granite. The pebbles are angular, subangular, and rounded, and many have blunt ends and concave fractures. Prof. J. B. Woodworth

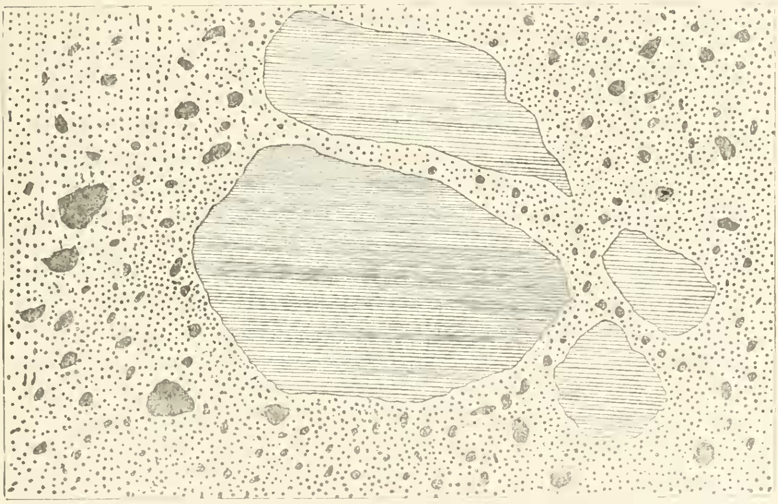

FIG. 1.— Disrupted sandstone in tillite: Squantum Southeast.

found a striated pebble at this locality. The striae are very faint, but with the aid of a pocket-lens appear perfectly characteristic.

As stated above, the tillite here has a probable thickness of about 600 feet. There is no good evidence that the bed is doubled by folding and from the most northerly exposure to the upper transition-beds the thickness is about as given. The lower contact with transition-beds is probably hidden beneath drift and beach-shingle. I believe that these lower transition-beds and a part of the Roxbury conglomerate underlie the tillite here and have not been faulted out. At the most northerly exposure and hence the lowest part of the tillite there is found a large mass of sandstone about 15 feet in diameter, the upper part of which is stratified with layers of slate alternating with sandstone. It appears to have been a part of an underlying bed which had been disrupted and dragged laterally upward into the till. The entire mass is surrounded with tillite. This is by far the largest block yet discovered in the tillite. In view of the fact that a bed of sandstone underlies the tillite at Atlantic, it is inferred that this sandstone mass is a part of a similar bed disrupted and included in the tillite. That the lower transition-beds and the Roxbury conglomerate are present, but hidden from view in this locality is also inferred from the large amount of fragments of the conglomerate found in the drift on Squantum just where they should be found. The stone-walls are made up chiefly of this variety of rock. The sizes of the pebbles in the Roxbury drift fragments average the same as in the Roxbury at Atlantic; lithological characters are the same. The texture of the Roxbury conglomerate in different localities is extremely variable, and hence to find the same texture in these fragments as at Atlantic, on nearly the same strike and only a short distance away, would indicate that they were not transported far but came from this vicinity. The great preponderance of these Roxbury fragments over other kinds of rock would also indicate a local origin. It is from this evidence that I have felt justified in believing that the tillite here has not been doubled, but is a bed shown in its actual thickness.

Near the very top of the tillite there is a multitude of slate fragments, which had their cleavage developed after inclusion in the tillite. They have very irregular shapes, none of them being water worn, and many of them bent and twisted as if they had been in a plastic condition when the ice moved over the surface. It is evident that here the ice plowed over a clay-bed, breaking it up and dragging the clay fragments, thus disrupted, upward into the till. Some of these fragments are large, one measuring four feet long by two feet wide in the other dimension. Most of them are about a foot long. Shearing has changed the original shapes in some cases. It is clear, however, that the bending, twisting, and tearing observed in these cases has not been brought about by shearing. See Plate 8.

Dr. Ellsworth Huntington, who was with Dr. La Forge and myself on our first visit to this locality, found a very remarkable case of deformation in a slate bed. The bed in question is about three feet thick. A part of this bed has been turned up so that it makes an angle of about 90° with the original bedding for several feet, and about ten feet farther on the bedding again assumes its original position. There are two cases of this sort here not far apart.

In the tillite of New South Wales, Australia, there is a case very similar to those just described. The exposure was found by Mr. C. S. Wilkinson in 1879 in Permian, or Permo-Carboniferous tillite. It bears so closely on our problem here that it will be well to quote Wilkinson in part. He says: — "In the section exposed in the quarries at Fort Macquaire, Woolloomooloo, Flagstaff Hill, and other places, may be seen angular boulders of the shale of all sizes up to 20 feet in diameter, embedded in the sandstone in a most confused manner, some of them standing on end as regards stratification and others inclined at all angles. These angular boulders occur nearly always immediately above the shale beds, and are mixed with very rounded pebbles of quartz: they are sometimes slightly curved as if they had been bent whilst in a semi-plastic condition, and the shale beds occasionally terminate abruptly, as though broken off. Had the boulders of soft shale been deposited in their present position by running water alone, their form would have been rounded instead of angular. It would appear that the shale beds must have been partly disturbed by some such agency as moving ice, the displaced fragments of shale becoming commingled with the sand and rolled pebbles carried along by the currents." (C. S. Wilkinson, p. 194).

Where the slate fragments appear near the transition-beds the proportion of pebbles to matrix is large, suggesting thin ice acting for a short time. There are some sandstone beds intercalated in the tillite which have a strike differing by 8°–10° from the strike of the main body of the slate just above. According to James Geikie (1895, p. 24), this is characteristic of beds intercalated in till. These beds must have dipped to the west when deposited.

Cleavage is well developed throughout these outcrops. See Plate **9**.

Criteria found: — A, B, C, D, E, F, H, J, K, L, M, N, O.

Locality 13. Squantum Head. At Squantum Head about three fourths of a mile north of the exposure just described, there is a massive outcrop of tillite. Strike on the north at contact with the slate N 48° E, dip 25° S. These strikes and dips were taken west of a north and south fault line to be described later. The thickness is probably 600 feet. The matrix is arenaceous and argillaceous. Boulders, boulderets, and pebbles are of all shapes and sizes up to three and one half feet in diameter. The proportion of rounded pebbles is larger than at the other Squantum exposure, although angular ones are very common, and the latter show the usual shapes due to glaciation. Dr. Arthur Keith, in the presence of Dr. La Forge and the writer, found one pebble which he considered at the time to be ice worn, and I found a pebble bearing several glacial striae (Plate **10**). The pebbles are of the usual kind found in the Roxbury formation: — granite, felsite, melaphyre, sandstone, quartzite, with some shale or slate fragments. The slate fragments found so abundantly in the exposure at Squantum farther south, and at Atlantic, are fewer here. A few may be seen near the contact with the slate. Near the middle of the tillite on the top of the hill there is an intercalated bed of water-laid gravel averaging about twenty feet thick. This bed may be seen again at the point of the Head on the north side. There is a north-south fault between the two exposures. On the glacial hypothesis it is apparent that the ice retreated and advanced again. On the shore to the north of a quarry which is on the top of the hill, may be seen a bed of sandstone about twenty feet thick and perhaps fifty feet from the bottom of the tillite at its contact with the lower slate. As this sandstone comes between two beds of tillite, it indicates another retreat and advance of the ice.

The fault mentioned above, cuts the tillite on a line near the front of the barn at the end of the road, and may be seen at the place on the shore where slate is encountered south of the dwelling house. Proceeding in a straight line from this point past the barn, the fault may be located on the north shore.

Dr. F. H. Lahee has observed plications in the slate south of the tillite bed which deserve notice here. The plications occur in layers of slate, and above and below such plicated layers the slate bedding has not been disturbed. The upper parts of the folds have been cut off, showing that the folding went on during the deposition. Dr. Lahee suggests that floating ice became grounded and compressed the layers, and later on when the same ice or other ice floated over these layers, the tops were cut off. Prof. James Geikie (1895, p. 271–274) has noted like plications in clay beds overlying the till at Portobello, Scotland, and he suggested grounding ice-rafts, as Lahee did, for the plicating agency. I have noted the same kind of folding in slate at Crow Point, Hingham, and at the Chestnut Hill fault locality, on Beacon Street west of Hammond Street, Chestnut Hill, but have not seen evidence of the cutting off of the folds at these localities. At the Atlantic exposure also folds in slate may be seen, with arches cut off as at Squantum Head. It is not impossible that the tops of these folds were removed by a swifter flow of water, as evinced at Atlantic by ripple-mark of fine sandstone above the folds. The same kind of folds, but not cut off, may be found in Pleistocene clays in many places in this country. Near Hanover, N. H., I have found many folds of this description. In view of the fact that the layers above and below the folds have not been deformed, it is difficult to see how the folds could have been formed by simple gravity, especially when it is noted that the folding and deposition were nearly contemporaneous.

There is some difference of opinion among geologists who have visited Squantum Head as to whether the tillite bed is doubled by folding and part of the exposure inverted. Dr. La Forge thinks that the strata on the north of the Head are inverted, and that the slate found both north and south of the tillite is the same bed. From a

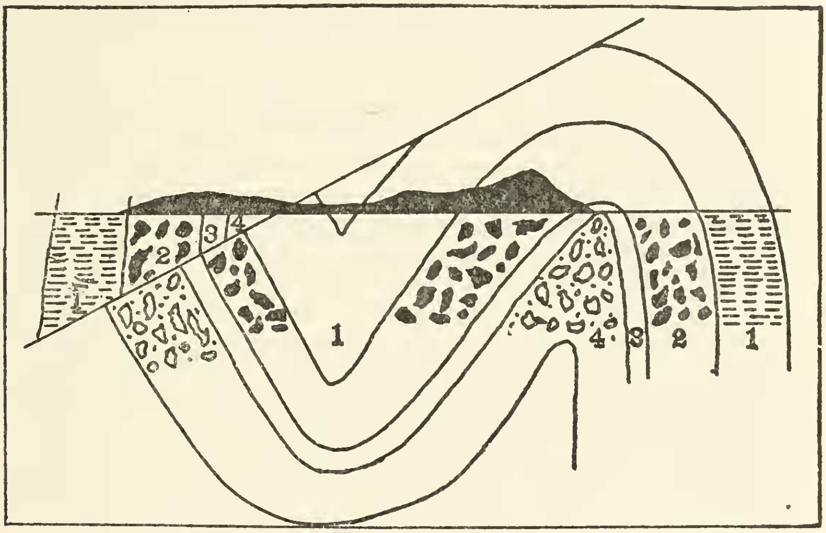

FIG. 2.— Hypothetical cross section of Squantum taken at right angles to the strike at Squantum Southeast. 1, Cambridge slate; 2, Tillite beds; 3, Lower slate; 4, Roxbury conglomerate.

study of the Atlantic locality and a comparison of the beds there with those at Squantum Head I have come to a different conclusion. It is necessary to recall the order of the beds at Atlantic. In the midst of the tillite at Atlantic there is an intercalated bed of gravel of small thickness. Near the middle of the main tillite at Squantum Head there is an intercalated bed of gravel from 15 to 30 feet thick. Under the main tillite formation at Atlantic there is a bed of sandstone about twenty-five feet thick. There is a bed of sandstone of about the same thickness on the north side of Squantum Head in contact with the main body of the tillite. Under the tillite at Atlantic there is, in all probability, as previously shown, another bed of tillite. At Squantum Head a bed of tillite lies to the north of the sandstone. Under the tillite at Atlantic there occur contorted slate and sandstone layers with a predominance of slate. Just north of the tillite at Squantum Head contorted slate with a few sandstone layers appear. Now these beds are not duplicated at Squantum Head as they should be if doubled by folding. The order is what it should be if the beds were not doubled. It is true that such intercalated beds as these are very variable, and a bed in one outcrop might not correspond to a similar bed similarly placed in another outcrop, but the close correspondence of these beds at Atlantic and Squantum Head is more likely to mean a similar order of deposition, and the chances of coincidence are rather small.

Slate layers, or "nests" are found, and also a few small fragments of slate. These layers or "nests" of slate may be found in the first few feet of tillite on both the north and the south sides of the Head. This deposition would be possible either in an advance, or retreat, or stationary condition of the ice, so it might mean either top or bottom, and could not be limited to one or the other. If there is no duplication of beds by folding the thickness of the tillite is 600 feet, otherwise 300 feet.

There is some evidence of floating ice at Squantum Head, in boulders found in the slate. Plate **7** shows such a boulder. This one is of amygdaloidal melaphyre twenty-seven inches long and fourteen inches wide, and was found at the western extremity of Squantum Head near the contact of the tillite with the slate.

Shearing has been very intense at Squantum Head, producing a cleavage with sharp dip to the northeast.

Criteria found:— A, B, C, D, E, F, G, H, J, K, L, M, N, O.

Locality 14. Brighton. In a vacant lot west of 55 North Beacon Street, there is an outcrop which has been a puzzle to local geologists. The strike at this locality is E 8° S, and the dip 28° N. The matrix, which is less abundant than the included pebbles, varies from arenaceous to argillaceous. There is stratification, and some assorting. The thickness exposed is about seventy-five feet. The pebbles are mostly rounded with a few angular and subangular examples. No striated pebbles have been found. Slate fragments abound. Mansfield (1906, p. 75) writes as follows in regard to this outcrop:—"This ledge has given rise to some controversy because of the appearance of slate masses that resemble clastic material but are two feet or more in length and nearly a foot in width. It has been maintained on the one hand that the slate masses are pebbles and on the other that they are pockets of slaty material laid down during the deposition of the conglomerate."

The slate masses referred to above are very similar to the slate lumps in the beds under the tillite at Atlantic. I consider their origin to be similar; disruption by moving ice and transportation by a glacial stream would explain it. No undoubted tillite has appeared north of Squantum Head and Roslindale, but clay fragments could have been transported by glacial streams beyond the ice-front for some distance. It is difficult to understand how clay particles could have been deposited in isolated pockets in so swift a stream as is indicated in this exposure by the size of the pebbles and boulders. Some of the boulders measure over a foot in diameter.

Cleavage is found at this exposure. It does not appear that this rock is tillite.

Locality 15. Waban. About half way between Eliot and Waban railroad stations there is an outcrop on the south side of the track. The strike is N 38° E, and the dip 53°N., as determined from overlying slate. This rock is not tillite but has every appearance of being on the tillite horizon. It is a very coarse conglomerate. The largest boulders are at least two feet in diameter, and are of angular, subangular, and rounded shapes. Melaphyre tuff appears to underlie this conglomerate. Above the conglomerate are beds of sandstone transitional to a thick body of slate, which appears to be the Cambridge slate. This very coarse conglomerate may well be outwash material from the glacier. It is several miles west of the most westerly outcrop of tillite.

Locality 16. Moon Island. At the most eastern extremity of Moon Island, which is, as a matter of fact, artificially connected with Squantum by a viaduct, there is an outcrop of the tillite. The strike is N 70° E, and the dip about vertical. The matrix is very fine suggesting the lower part of a tillite bed. There is no stratification and the included rock fragments are mostly angular, and subangular. No striated pebbles have been searched for. Some intercalated beds of sandstone and conglomerate may be seen. As this place was found very recently it does not appear on the locality map, and the criteria for tillite are not yet as complete as possible. Moon Island is a drumlin, and at the tillite outcrop well-exposed till lies on the tillite.

Criteria found:— A, B, C, D, J, K, L.

Locality 17. Huit's Cove. At Huit's Cove, Hingham, on the east shore of Weymouth Back River, there is an exposure of the very top of the tillite and transition-beds and the uppermost part of the slate formation. The strike here is N 12° E, and the dip 70° N. The tillite exposure proper is very small and little can be said of it. The matrix of the tillite is sandy. The pebbles and boulders are angular, subangular, and rounded. The transition-beds are very much like those at Squantum Southeast:— large boulders and slate fragments mingled in an unstratified mass, with here and there thin layers of sandstone. An ice-rafted boulder was extricated from the slate, and many more may be seen.

Melaphyre appears about fifteen feet below the tillite, but whether as a flow, dike, or sill has not been satisfactorily determined.

Crosby studied this locality some years ago and wrote (1894, p. 249) as follows concerning the tillite:— "The pebbles are of all sizes up to a yard or more in diameter, the largest observed being a boulder of coarse granite over 5 feet in length. Furthermore the various sizes are jumbled together promiscuously without evident assorting or stratification, looking not unlike an indurated till or boulder clay." Crosby discovered some exotic limestone here, which he thinks came from the north. He did not prove his conclusions, however, on this point (Crosby, 1894, p. 265–266).

Cleavage is well marked.

Criteria found:— A, B, C, D, F, J, L, M, N, O.

Locality.— Arnold Arboretum. While the proof of this paper was in press, I discovered a large tillite locality in the Arnold Arboretum north of Peters Hill. It is the ridge covered by evergreens on the eastern margin of the Arboretum grounds. This is along the same strike as Locality 3, but farther northeast. No contacts with other beds have been seen, so it is impossible to obtain strike and tip. Criteria observed during one visit:— A, B, C, D, J, M.

Review of localities with criteria.

The list of localities on the following page with the criteria of tillite found at each, are arranged as nearly as possible according to the extent of outcrop, and favorable conditions for search.

The list below shows that where there is ample opportunity, abundant criteria are usually found. It must be noted that a thorough examination of some outcrops has been impracticable as yet, owing to location in private grounds or cemeteries. Other outcrops are so limited in extent that they show only the presence of the formation.

This will explain why some of the descriptions give so few glacial characters, and does not mean that such an outcrop would not reveal many more glacial characters if opportunity were granted to hammer and blast.

In spite of the small outcrops and those which I have not been able to investigate properly, the average percentage of criteria for all localities so far as the present investigation has gone, is slightly over 61%. Taking the first five of the localities given in the list, and the percentage of criteria is 80%. The best locality of all, Squantum Head, gives a percentage of 93%. A further search for striated pebbles by the blasting method would probably raise these percentages materially. So far nothing but geological hammers and chisels have been used. The striated rock-floor or pavement is entirely wanting. There is no prospect of finding this on account of the nature of the beds underlying the tillite.

Locality	12.	Squantum Southeast:—	A,B,C,D,E,F,H,J,K,L,M,N,O.
"	13.	Squantum Head:—	A,B,C,D,E,F,G,H,J,K,L,M,N,O.
"	3.	Roslindale:—	A,B,C,D,F,G,H,J,K,L,M.
"	1.	Hyde Park:—	A,B,C,D,E,F,G,H,J,K,L,M.
"	10.	Atlantic:—	A,B,C,D,F,H,J,K,L,M.
"	5.	So. Forest Hills:—	A,B,C,D,J,L.
"	9.	Franklin Field:—	A,B,C,D,E,F,G,H,J,K,L.
"	11.	Atlantic-Squantum Kn:—	A,B,C,D,J,K,L,M.
"	17.	Huit's Cove:—	A,B,C,D,F,J,L,M,N,O.
"	16.	Moon Island:—	A,B,C,D,J,K,L.
"	8.	Morton St:—	A,B,C,D,F,H,J,L,M.
"	6.	Forest Hills Cemetery:—	A,B,C,D,J,L,M,O.
"	2.	Milton Upper Mills:—	A,B,C,D,F,J,L.
"	4.	Roslindale:—	A,B,C,D,F,J,L.
"	7.	New Calgary Cemetery:—	A,B,C,D,J.

In view of the sum total of the evidence found in these different localities, I am forced to the opinion that there is true tillite in the Boston Basin. No other theory explains the evidence so far brought to light.

Doubtful localities.

About 500 feet northwest of Canterbury Street on Morton Street southeast of Forest Hills Cemetery, there is a conglomerate outcrop.

In an open field 300 yards south of Walkhill Street and one fourth of a mile southeast of Harvard Street there is an outcrop of slate, sandstone, and perhaps tillite.

On Blue Hill Avenue opposite Hazelton Street, just north of Walkhill Street, there is an outcrop of slate and an unstratified conglomeratic mass resembling tillite. Other doubtful deposits are as follows: —

On railroad between Wollaston and Quincy.

Black's Creek, one fourth mile west of railroad.

North Quincy, one half mile northeast of Atlantic station.

Between Florence St. and Hyde Park Avenue, near Mt. Hope station.

Cleavage.

As noted in the description given of the tillite, evidence of intense shearing is found in every locality. The cleavage dips, as a rule, in a northeasterly direction. The shearing is beautifully shown in some of the pebbles from the tillite, which have been split in two and the parts turned as if on a pivot. In a boulderet found at Squantum Head one half has been sheared from the other about one third of an inch at one end, while at the other end only slight displacement has been effected. Some of the pebbles have been indented, and others flattened and stretched. A great many have a puckered or wrinkled appearance suggesting flow-effects. Striations due to diastrophic movements may be found frequently and are entirely different from the glacial striae. Almost all the surfaces of the rock fragments in the tillite have been thus affected in some manner. With all the shearing, and other diastrophic movements which the pebbles in the tillite have been through it is not to be wondered at that glacially striated pebbles and boulders are rarely found. Occasionally one of the surfaces of a pebble has been so placed in the matrix of the tillite as to escape the violent diastrophic movements.

Some of the tillite exposures have been weathered and it is nearly useless to look for striae in these. At Hyde Park where Dr. La Forge found the best striated pebble yet brought to light, the rock has been freshly blasted and there is more hope of a successful search. There is also an advantage here in a search for striations, in that the bottom of the tillite is exposed. As mentioned above, till contains finer materials and more striated pebbles at the bottom than at the top (Stone, 1899, p. 29–30). Wherever the bottom of the tillite has been found the matrix is much finer than in the places where the top is exposed. The difficulties experienced in extricating pebbles from the fresh matrix of the bottom of the tillite has been very great. Most of those taken out have been broken in many fragments. All of the striated pebbles but one were found near the bottom of the tillite. Until some outcrop is discovered where cleavage is absent, or much less than at any exposure yet found, it is not likely that many pebbles with glacial striae will be found.

The mud-flow idea.

Stanislaus Meunier tried to prove that the till of Switzerland was of mud-flow origin. He did not prove his theory for Switzerland and if he had been familiar with the immense areas of till in North America he might have come to a different conclusion. That till does flow under the ice when full of water, no glacial geologists will deny. There is no reason why it should not flow under such tremendous pressures, and flow-structure in till is often found. (Meunier, 1899).

The mud-flows most commonly known are composed of mud and disaggregated rock. The rocks from which flows are most likely to come are shales or slates or argillaceous schists. Granite and sandstone or conglomerate would not be so apt to flow even in a disintegrated condition. Mud-flows of this kind require a rather steep gradient, and are limited to comparatively small areas. The materials in the tillite under discussion are fresh and angular, showing no weathering, and are not of the kinds found ordinarily in mud-flows. There is no evidence of a steep gradient in the Roxbury series. The area of the tillite is more than 100 square miles, so far as known by outcrops and allowance for folding. The total original area was probably several hundred square miles or even more.

The mud-flows of volcanic origin are usually composed of a large amount of volcanic materials, such as pumice, ash, scoria, bombs, lapilli, etc. They are also, ordinarily, of comparatively small dimensions. In the tillite no such evidence of a volcanic mud-flow has been found.

The volcanic action, however, near the tillite horizon shown in the lava flow at Brighton and certain other places, may have no other effect than to cloud, for many, the whole issue of the glacial origin of the Roxbury series. Torrential waters as well as mud-flows are common in volcanic eruptions and some volcanic materials are found in the tillite, although the quantity is negligible when compared with the non-volcanic materials. In some regions glacial deposits are made up chiefly of volcanic ejections. In Glaciers of North America Prof. I. C. Russell quotes Dr. C. Willard Hayes as follows:—"The moraine in front of the Klutlan is the largest accumulated by any of the interior glaciers. It is composed very largely of the white volcanic tufa already described, but with this are mingled many angular fragments of amygdaloidal lava and a few of granite and gneiss. Much of the moraine has been removed by streams flowing from the glacier, but remnants 2000 feet or more in thickness extend nearly across to the highland north of the valley." (Russell, 1901, p. 106).

Although striated rock fragments might be found in a mud-flow, I have yet to find a reference in the literature to such, from an actual mud-flow. Even if striated stones were found, it is not likely that all the other evidence of glaciation would be found. Those who would have the tillite under discussion a mud-flow, have also the *onus probandi* on their side.

The age of the Roxbury series.

The exact age of the tillite is still uncertain. The lithological characters of the Roxbury series resemble closely those of the Carboniferous and Permian of the Narragansett and Norfolk Basins. The Roxbury series, which consist of the Roxbury conglomerate, the Squantum tillite, and the Cambridge slate, is newer than the Cambrian as proved by pebbles in it of the granite which cuts the Cambrian. The Roxbury series lie, without much doubt on the same granitic surface of erosion which underlies the Carboniferous of the Narragansett and Norfolk Basins.

All that can be said at present is, that the tillite is of Permo-Carboniferous age. The fact that the Permian glaciation was so widespread, and that new evidence of it is coming in so rapidly, makes it very probable that the tillite is of Permian age. No fossils of determinative value have been found, although Burr and Burke did find a fossil tree-trunk in the Roxbury conglomerate proper. (Burr, H. T., and Burke, R. E., 1900, p. 179–184).

History of the tillite.

A study of the sediments of the Boston Basin gives some idea of the physiography of the region, during late Carboniferous or Permian times. The area in which the sediments were deposited extended far and wide beyond the present limits of the deposits. That the area of deposition was low relatively to the surrounding country is certain, but that it was at sea-level is not so easily determined. Towards the close of deposition the land must have been subsiding as shown by the thick bed of slate over the tillite. In order for till to be preserved as tillite, it must ordinarily be on a surface which is subsiding at or soon after the time of the retreat of the ice-sheet. Any till deposit above sea-level on a stationary or rising surface would almost invariably be eroded long before later subsidence could remove it beyond the wear and tear of the elements. Whether the slate above the tillite is of marine or fresh water origin it is not possible at present to say. No clearly marine fossils have been found in it, and so far as this negative evidence goes it is more probable that this slate is of lacustrine origin. The absence of fossils, however, does not settle the question. Marine life in the Permian seas was scarce or wanting altogether in many places, and furthermore fossils are not found everywhere in the marine clays of Massachusetts and Maine and other places where marine clay of Pleistocene age outcrops. If volcanoes were situated then as now near the continental margins, the sea might not have been many miles away, for volcanic action was associated with the deposition of these beds as shown by melaphyre flows in several places in the Basin. According to Bailey Willis (1909, p. 403–405) land extended at least 100 miles in a southeasterly direction from Boston and probably much farther than this. That there was high land to the southeast appears probable also from a study of the tillite. The evidence so far points to a southeasterly origin for the ice which formed the tillite. A discussion of this question of direction comes naturally in the history of the appearance of the tillite as shown best in the Atlantic exposure, and in a study of some features of the tillite found at the southeastern Squantum exposure.

The Roxbury conglomerate proper at Atlantic exposes a thickness of about 520 feet. The lowest part shows rather small pebbles averaging about one inch in diameter. Farther up the pebbles increase in size gradually, while in the transition-beds below the tillite the pebbles are larger, averaging about four inches. It would seem very probable that this gradual increase in the size of the pebbles heralded the coming ice-sheet by wetter conditions or by a shorter distance from the source, as the ice drew nearer. If the larger size of the pebbles was due to more water and greater velocity, the pebbles should be as rounded as formerly, but if the approach of the ice was the cause of the size, the pebbles should be more angular as well as larger. The latter appears to be the case.

Above the Roxbury a sandstone bed was formed, indicating slower stream-action. A bed of conglomerate was then laid down, indicating swifter stream-action. Another sandstone bed was then deposited. At this point a new phenomenon is met with. Above this last mentioned sandstone comes a conglomeratic mass which differs from the Roxbury in having the fragments and lenticular layers of slate, mentioned above in the description of this locality. From a study of this bed I infer that the ice had come near when these fragments of clay were deposited. Just above this bed come about forty-seven feet of slate and sandstone layers with ripple-mark and some boulderets from eight to ten inches in diameter. At this time the ice must have made a temporary halt or retreat. At least deeper or slower water conditions prevailed. Certain layers in this slate bed are contorted, and immediately above and below these layers there are no signs of contortion. The tops of the arches are eroded, thus proving that the contortions were made while the deposition of the slate beds was going on. The ripple-mark suggests a stream of slow speed which might very well have eroded the tops of these folds. Above these slate and sandstone layers occurs another conglomeratic mass with more slate fragments and probably a bed of tillite. At this place there are no good exposures for fifty or sixty feet; but tillite, which I believe to be *in situ* outcrops, in one place. There is no tillite immediately to the north or northwest of this spot, so it does not seem probable that this outcrop is a boulder. Above this horizon comes a bed of sandstone about twenty feet thick. In the midst of this sandstone are some very thin layers of conglomerate and a few slate fragments, one of which measures eight by ten inches. These last mentioned beds indicate another advance and retreat of the ice-sheet. The relatively thick sandstone bed shows that the ice retreated for some distance and might or might not indicate an interglacial epoch.

Above this sandstone comes the main body of the tillite. The difference between the tillite and the water-laid conglomerate which contains the slate lumps is obvious. The contact between the sandstone and the tillite is very ragged, showing disruption of the sandstone. The tillite pierces the sandstone as if pushed into it. With the exception of very thin layers of slaty material no intercalated beds are met with in this exposure for about 150 feet, when a bed of conglomerate and sandstone is found not over two feet thick. It is probable that this bed is the equivalent of the bed of coarse gravel found at Squantum Head and indicates a retreat of the ice. Above this bed the tillite is continuous as far as the outcrops extend, but it is evident that not much more than one half of the tillite is exposed at this locality.

To obtain an idea of the sequence of events near the top of the tillite a study of the exposure at the southeast Squantum locality is best, as the section is almost all exposed to view for several hundred feet along the shore. Of this exposure only the uppermost part will be considered.

Commencing on the little high-tide island opposite the end of the road, thin intercalated beds of sandstone and slate are found. One of these beds has a plication in an east-west direction which may have been made by ice-push. It does not seem probable that this plication was caused by diastrophic movement, not only because the movement was at right angles to the main direction of folding, but also because there are no signs of plication above or below this bed. It is of course possible that there was diastrophic movement transverse to the main direction of folding, but if this had been the case here it would seem that there should be some evidence of it above and below the plication.

Above this first intercalated bed, near the top of the tillite, there are two more similar beds, and between each, undoubted tillite. In places there are very fine layers of slaty material not more than one sixteenth of an inch thick. Pebbles are pressed into these thus cutting them off and deforming them. These tiny clay-threads suggest melting of the ice and trickling of water laden with clay, between the ice and the till.

A large block of pink granite, in the tillite on this island, six feet long and one foot wide, is important in showing transportation without wear. (Plate 9). The block is angular. It is not easy to see how this block could have been transported in its present fresh condition by any other agency than an iceberg or a glacier.

Returning to the main land and proceeding in a southerly direction along the shore, the transition-beds from the tillite to the main slate-body can be studied with ease. The beds intercalated in the tillite grow in thickness towards the top, suggesting longer retreats of the ice each time. The proportion of pebbles to matrix increases, and slate fragments of all shapes and sizes make their appearance. The tillite now suggests very thin ice acting for short periods, for the pebbles are very abundant. Retreats and advances were of shorter duration. The reappearance of the slate fragments at the top of the tillite is to be explained, I believe, in these advances and retreats of the ice. The ice retreated, and deposits of gravel, sand, and clay were made on the ground left vacant by the retreat. Again the ice advanced, ploughing up the beds formed at its front and making a new till composed of parts of gravel, sand, and clay-beds.

Disrupted sandstone and slate beds come above this slate lump horizon, and then appears the main body of the slate, the highest member of the series in the Boston Basin. The ice had then retreated permanently from the Basin, and the land had subsided, and continued to subside until several hundreds of feet of clay had been deposited.

The direction of movement of the glacier which produced the tillite is most important. There are a number of considerations which indicate a direction from the southeast to the northwest. Though not certainly due to ice thrust, the plication of the intercalated bed mentioned above, points to such a direction of movement. Again in the description of this locality (page 155) it should be noticed that the beds intercalated in the tillite strike at an angle of from eight to ten degrees more east than the main body of the slate higher up. This must mean either a diastrophic change in the attitude of the beds, or that the intercalated beds sloped downwards towards the level of the water in which the slate was deposited. There is no evidence of an eroded zone between the transition-beds and the slate, so it does not appear that there is any unconformity. The beds in question slope from the east towards the west. According to Prof. James Geikie (1895, p. 24), beds intercalated in till are diagonal and not as a rule horizontal, and slope towards the ice-front. It would appear that the beds in the tillite at Squantum Southeast dipped westward, and if this was the case, and the difference in strike is not due to diastrophic movement, there would seem to be good reason for believing that the ice came from an easterly direction. Then again, a consideration of the slate fragments might also indicate an east-west direction of ice movement. In the tillite at Hyde Park, Milton Upper Mills, Roslindale, I have not observed slate fragments. At Squantum, and Atlantic the rock fragments in the tillite show a majority of pink granite, with melaphyre and quartzite coming next in abundance. If the ice had come from the north, the granite fragments could be explained, but not the melaphyre. If it had come from the west, the melaphyre fragments could be explained, but no pink granite of the variety found in the tillite is known in that direction. If the ice came from the south the pink granite could be accounted for, but not the melaphyre. If the ice came from the southeast, however, both the pink granite and the melaphyre are explained, for at Nantasket, Cohasset, and Hingham these rocks are found *in situ*. The fact that the largest boulders found in the tillite are of pink granite and melaphyre, and that these are found together, suggests a place of origin for both near the same locality. I have not forgotten that Pleistocene drift may hide some outcrops, and that the above suggestion cannot be proved, but so far as known outcrops go, it is a legitimate speculation, and when joined to the other evidence of the direction of ice movement appears logical and what would be expected if the ice came from the southeast. Another indication of the direction of ice movement is found in the limited westward extension of the tillite. To the west beyond Roslindale no true tillite has yet been found. Southwest of Mt. Benedict in the woods there is a layer of very large boulders in the conglomerate. One of them measures over three feet in diameter and most of them are over two feet. There is a suggestion here of outwash materials and swift water. At Waban in what appears to be the tillite horizon there are more large boulders, but no tillite. To the north of Squantum Head and Roslindale no undoubted tillite has been found. All of these considerations point to an easterly or southeasterly place of origin. The fact that no terminal moraine has been found is no proof that there was none. The width of a frontal moraine belt varies from a few feet to twenty miles for a continental glacier. A wide belt would probably appear somewhere in these highly folded strata of the Boston Basin, but a narrow belt might easily have been folded under or already eroded and thus lost to sight. Outwash materials, however, would extend for miles beyond the terminal moraine, and that some of the coarse gravels west of Roslindale are of such origin appears possible.

It is impossible to say whether the glacier which formed the tillite was of the continental or piedmont type. The large thickness of the tillite might indicate either, for thick till is not limited to continental glaciers, but is found in the low lands of the Alps at the present day. The thickest till is almost always found in the valleys (J. Geikie, 1895, p. 24). The boulders and fragments of limestone found by Crosby at Huit's Cove, Hingham, in the tillite, seem to be real exotics, and this might indicate that the ice came from some distance. It is necessary to suspend judgment on this question of type of the glacier. The Malaspina glacier is about seventy miles long and twenty-five miles wide. A glacier of this size would answer all the requirements of the discoveries in the Boston Basin. The extent of the tillite precludes anything smaller than a piedmont glacier.

In the vicinity of Squantum and Atlantic the tillite is seen to be made up of three separate beds divided by the two intercalated beds mentioned above. If the intercalated beds near the top are considered, the tillite is divided still farther. Whether the two main intercalated beds indicate interglacial epochs is a question of importance. That such beds indicate milder conditions there can be no doubt, but that such milder conditions would mean an interglacial epoch of long duration is more difficult to prove. All that can be said, therefore, in regard to these two beds in the tillite is, that they prove milder conditions and temporary retreats of the ice-sheet, and that the cause of glacial periods fluctuated in the distant geological past much as it did during the Pleistocene period. It would be a difficult matter even with the aid of fossil plants, to prove an extended interglacial epoch in such a limited deposit as that found in the Boston Basin, unless other evidences of interglacial conditions were present.

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Bibliography.

Barton, G. H.
See Crosby, W. O., and Barton, G. H.

Bascom, Florence.
Volcanics of Neponset valley, Massachusetts. Bull. Geol. soc. Amer., 1900, **11**, p. 115–126.

Blackwelder, Eliot.
See Willis, Bailey, Blackwelder, Eliot, and Sargent, R. H.

Blanford, W. T.
On the nature and probable origin of the superficial deposits in the valleys and deserts of central Persia. Quart. journ. Geol. soc. London, 1873, **29**, p. 493–501.

Branner, J. C.
The supposed glaciation of Brazil. Journ. geol., 1893, **1**, p. 753–772.

Brock, R. W.
See McConnell, R. S., and Brock, R. W.

Brückner, E.
Die vergletscherung des salzachgebietes. Geogr. abhandl., 1886, **1**, p. 1–183, 3 pls., 3 maps.
See Penck, A., Brückner, Edward, and Du Pasquier, Léon.

Burke, R. E.
See Burr, H. T., and Burke, R. E.

Burr, H. T.
A new Lower Cambrian fauna from eastern Massachusetts. Amer. geol., 1900, **25**, p. 41–50.
The structural relations of the amygdaloidal melaphyr in Brookline, Newton, and Brighton, Mass. Bull. M. C. Z., 1901, **38**, p. 51–70, pl. 1–2.

Burr, H. T. and Burke, R. E.
The occurrence of fossils in the Roxbury conglomerate. Proc. Bost. soc. nat. hist., 1900, **29**, p. 179–184, pl. 1.

Chamberlin, T. C., and Salisbury, R. D.
Geology. 3 vols., New York, 1904–1906.

Coleman, A. P.
A Lower Huronian ice age. Amer. journ. sci., 1907, ser. 4, **23**, p. 187–192.
Glacial periods and their bearing on geological theories. Bull. Geol. soc. Amer., 1908, **19**, p. 347–366.

Crosby, W. O.
Contributions to the geology of eastern Massachusetts. Occ. papers Bost. soc. nat. hist., 1880, **3**.
Geological history of the Boston Basin. Proc. Bost. soc. nat. hist., 1890, **25**, p. 10–17.
Geology of the Boston Basin. Occ. papers Bost. soc. nat. hist., 1894–1900, **4**, pt. 2, p. 249, 265–266; pt. 3, p. 289–293, 499–505.

Crosby, W. O. and Barton, G. H.

Extension of the Carboniferous formation in Massachusetts. Amer. journ. sci., 1880, ser. 3, **20**, p. 416–420.

Dale, T. N.

A contribution to the geology of Rhode Island. Proc. Bost. soc. nat. hist., 1883, **22**, p. 179–201, pl. 1–3.

David, T. W. E.

Evidences of glacial action in Australia in Permo-Carboniferous time. Quart. jour. Geol. soc. London, 1896, **52**, p. 289–301, pl. 12.

Davis, W. M.

Causes of Permo-Carboniferous glaciation. Journ. geol., 1908, **16**, p. 79–82.

A journey across Turkestan. Carnegie inst. Publ., 1905, **26**, p. 21–120.

Dodge, W. W.

Notes on the geology of eastern Massachusetts. Proc. Bost. soc. nat. hist., 1875, **17**, p. 388–419.

Du Pasquier, Léon.

See Penck, A., Brückner, E., and Du Pasquier, L.

Emerson, B. K.

On the Triassic of Massachusetts. Bull. Geol. soc. Amer., 1891, **2**, p. 451–456, pl. 17.

Emmons, S. F.

Review of the geological literature of the South African Republic. Journ. geol., 1896, **4**, p. 1–22.

Fairchild, H. L.

Beach structure in Medina sandstone. Amer. geol., 1901, **28**, p. 9–14, pl. 2–6.

Foerste, A. F.

The paleontological horizon of the limestone at Nahant, Mass. Proc. Bost. soc. nat. hist., 1889, **24**, p. 261–263.

See Shaler, N. S., Woodworth, J. B., and Foerste, A. F.

Geikie, Archibald.

Text book of geology. Ed. 4, 2 vols., London, 1903.

Geikie, James.

The great ice age. Ed. 3, New York, 1895.

Gilbert, G. K.

Lake Bonneville. U. S. G. S. Monograph, 1890, **1**.

Green, A. H.

A contribution to the geology and physical geography of the Cape Colony. Quart. journ. Geol. soc., London, 1888, **44**, p. 239–269.

Halle, T. G.

On the geological structure and history of the Falkland Islands. Bull. Geol. inst. Univ. Upsala, 1912, **11**, p. 115–229.

Hayes, C. W.

An expedition through the Yukon District. Nat. geog. mag., 1892, **4**, p. 117–162, pl. 18–20.

Haynes, W. P.

Discovery of bivalve Crustacea in the Coal measures near Pawtucket, R. I. Science, 1913, new ser., **37**, p. 191–192.

Howchin, Walter.

Australian glaciations. Journ. geol., 1912, **20**, p. 193–227.

Howe, Ernest.

Landslides in the San Juan Mountains, Colorado, including a consideration of their causes and their classification. U. S. G. S. Prof. paper, 1909, **67**.

Huntington, Ellsworth.

The basin of eastern Persia and Sistan. Carnegie inst. Publ., 1905, **26**, p. 217–318.

Some characteristics of the glacial period in non-glaciated regions. Bull. Geol. soc. Amer., 1907, **18**, p. 351–388, pl. 31–39.

Johnson, W. D.

The high plains and their utilization. U. S. G. S. Ann. rept., 1901, **21**, pt. 4, p. 601–742, pl. 113–156.

La Forge, Laurence.

See Sayles, R. W., and La Forge, Laurence.

Lahee, F. H.

Relations of the degree of metamorphism to structure and to acid igneous intrusion in the Narragansett Basin, Rhode Island. Amer. journ. sci., 1912, ser. 4, **33**, p. 249–262, 354–372, 447–469.

McConnell, R. G. and Brock, R. W.

Report on the great landslide at Frank, Alta. 1903. Ann. rept. Dept. interior Canada, 1903, part 8.

Mansfield, G. R.

The origin and structure of the Roxbury conglomerate. Bull. M. C. Z., 1906, **49**, p. 89–272, 7 pls.

Meunier, Stanislas.

La géologie expérimentale. Paris, 1899.

Penck, Albrecht.

Die vergletscherung der Deutschen Alpen. Leipzig, 1882.

Penck, Albrecht, and Brückner, E.

Die Alpen in eiszeitalter. Leipzig, 1903.

Penck, Albrecht, Brückner, E., and Du Pasquier, L.

Le systeme glaciaire des Alpes. Guide Congres geol. intern. Zurich, 1894.

Preller, C. S. Du R.

On fluvio-glacial and interglacial deposits in Switzerland. Quart. journ. Geol. soc. London, 1895, **51**, p. 369–386.

On Pliocene glacio-fluviatile conglomerates in subalpine France and Switzerland. Quart. journ. Geol. soc. London, 1902, **58**, p. 450–467.

Pumpelly, Raphael W.

Physiographic observations between the Syr Darya and Lake Kara Kul, on the Pamir, in 1903. Carnegie inst. Publ., 1905, **26**, p. 121–216.

Ramsey, A. C.
On the occurrence of angular, subangular, polished, and striated fragments and boulders in the Permian breccia of Shropshire, Worcestershire, &c.; and on the probable existence of glaciers and icebergs in the Permian epoch. Quart. journ. Geol. soc. London, 1855, **11**, p. 185–205.

Russell, I. C.
Glaciers of North America. Boston. 1901.

Salisbury, R. D.
Agencies which transport materials on the earth's surface. Journ. geol., 1895, **3**, p. 70–97.
See Chamberlin, T. C. and Salisbury, R. D.

Sargent, R. H.
See Willis, Bailey, Blackwelder, Eliot, and Sargent, R. H.

Sayles, R. W., and LaForge, Laurence.
The glacial origin of the Roxbury conglomerate. Science, 1910, new ser., **32**, p. 723–724.

Shaler, N. S.
[Note on the geological section at Chestnut Hill Reservoir, Mass.]. Proc. Bost. soc. nat. hist., 1869, **13**, p. 172–177.
Note on the geological relations of Boston and Narragansett Bays. Proc. Bost. soc. nat. hist., 1875, **17**, p. 488–490.
On the geology of the Cambrian district of Bristol County, Massachusetts. Bull. M. C. Z., 1888, **16**, p. 13–26, map.

Shaler, N. S., Woodworth, J. B., and Foerste, A. F.
Geology of the Narragansett Basin. U. S. G. S. Monograph, 1899, **33**.

Stone, G. H.
On the scratched and facetted stones of the Salt Range, India. Geol. mag., 1889, Dec. 3, **6**, p. 415–425.
The glacial gravels of Maine and their associated deposits. U. S. G. S. Monograph, 1899, **34**.

Taff, Joseph A.
Ice-borne boulder deposits in mid-Carboniferous marine shells. Bull. Geol. soc. Amer., 1910, **20**, p. 701–702.

Waagen, Wilhelm.
Mittheilung eines Briefes von Herrn A. Derby über Spuren einer carbonen Eiszeit in Südamerika. Neues jahrb., 1888, **2**, p. 172–176.

White, C. D.
Carboniferous glaciation in the southern and eastern hemispheres, with some notes on the Glossopteris-flora. Amer. geol., 1889, **3**, p. 299–330.

Wilkinson, C. S.
Note on the occurrence of remarkable boulders in the Hawkesbury rocks. Journ. and proc. Royal soc. N. S. W., 1880, **13**, p. 105–108.

Williams, G. H.
The distribution of ancient volcanic rocks along the eastern border of North America. Journ. geol., 1894, **2**, p. 1–31.

Willis, Bailey.
Paleogeographic maps of North America. 8. Latest Paleozoic North America. Journ. geol., 1909, **17**, p. 403–405.
Willis, Bailey, Blackwelder, Eliot and Sargent, R. H.
Research in China. Carnegie inst. Publ., 1907, **54, 1**, part 1.
Wolff, J. E.
The great dike at Hough's Neck, Quincy, Mass. Bull. M. C. Z., 1882, **7**, p. 231–242.
Woodworth, J. B.
Geological expedition to Brazil and Chile, 1908–1909. Bull. M. C. Z., 1912, **56**, p. 1–138, 37 pls.
Boulder beds of the Caney shales at Talihina, Oklahoma. Bull. Geol. soc. Amer., 1912, **23**, p. 457–462, pl. 23–24.
See Shaler, N. S., Woodworth, J. B., and Foerste, A. F.